P-8.1 Compare the strong and weak nuclear forces in terms of their roles in radioactivity.

Revised Taxonomy Levels 2.6 B Compare conceptual knowledge

In physical science students were introduced to the nucleus, protons, neutrons and radioactive isotopes.

It is essential for students to:

- Understand that the nucleus consists of protons and neutrons and that there is a large repulsive force between the protons.
- Understand that nuclei are stable because the short-range, strong (nuclear) force overcomes the repulsive electromagnetic force between protons.
  There are strong nuclear forces associated with:
  - Neutron-neutron interactions,
  - Proton-neutron interactions, and
  - Proton-proton interactions.
- Understand that the strong force is about the same for each type of interaction but the proton-proton interaction is partially mitigated by the repulsive electromagnetic force, so the net attractive force has a lower magnitude than in the other interactions.
- Understand that smaller nuclei are most stable when the number of protons is equal to the number of neutrons.
- Understand that larger nuclei are more stable when the number of neutrons is greater than the number of protons.
  - The addition of extra neutrons increases the total attractive force while not adding to the repulsive force.
  - When the atomic number is 83 or greater the repulsive forces between the protons cannot be compensated by additional neutrons.
  - Elements that contain more that 83 protons do not have stable nuclei.
- Understand that beta decay requires the introduction of an additional type of interaction called the weak force.
  - A beta decay results when a neutron transforms into a proton and a beta particle (or electron).

Teacher note: The Standard Model of particle physics describes the electromagnetic interaction and the weak interaction as two different aspects of a single electroweak interaction. The weak interaction changes one flavor of quark into another. The weak interaction is the only process in which a quark can change to another quark. In beta decay, a down quark in the neutron changes into an up quark by emitting a W boson, which then breaks up into a high-energy electron (beta particle) and an electron antineutrino leaving behind a proton.

Discussion of quark transmutation, W bosons, and antineutrinos are beyond the scope of this course.

Assessment
As the indicator states, the major focus of assessment is to compare (detect correspondences). Students should compare the effects of different forces and their roles in radioactivity.

Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments should show that students can compare the relationships between the forces in the nucleus and their roles in radioactivity.

P-8.2 Compare the nuclear binding energy to the energy released during a nuclear reaction, given the atomic masses of the constituent particles.

Revised Taxonomy Levels 2.6 B Compare conceptual knowledge

In physical science the students were introduced to nuclear fission and fusion. Students were introduced to the concept of mass turning into energy in nuclear reactions and practical applications of this concept.

It is essential for the students to:

- Understand that the total mass of a nucleus is always less than the sum of the masses of its nucleons.
  - Because mass is another manifestation of energy, the total energy of the bound system (the nucleus) is less than the combined energy of the separated nucleons.
- Understand that this difference in (mass equivalent) energy is called the binding energy of the nucleus and can be thought of as the energy that must be added to a nucleus to break it apart into its components.
  - In order to separate a nucleus into protons and neutrons energy must be put into the system.
- Compare the nuclear mass defect and nuclear binding energy given the mass of the nucleons.

Assessment

As the indicator states, the major focus of assessment is to <u>compare</u> (detect correspondences). Students should compare the nuclear binding energy to the energy released during a nuclear reaction.

Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments should show that students can compare the relationships between nuclear binding energy and the energy released during a nuclear reaction.

P-8.3 Predict the resulting isotope of a given alpha, beta, or gamma emission.

Revised Taxonomy Levels 2.5 B Predict (infer) procedural knowledge

In physical science students were introduced to the concept of radioactive isotopes. Alpha, beta, and gamma emission may not have been covered.

It is essential for students to:

- Understand that a beta decay results when a neutron transforms into a proton and a beta particle.
- Understand that an alpha particle is a helium nucleus that consists of two neutrons and two protons.
- Predict the resulting isotopes from an alpha or beta decay when told which type of decay will occur.
  - **It not essential** that students understand neutrino or antineutrino emissions that may occur with beta decay.
- Understand that after a nucleus undergoes a radioactive decay it is often left in an excited state. The nucleus may undergo a second decay to a lower energy state by emitting one or more photons. The photons emitted in such a de-excitation process are called gamma rays which have a very high energy relative to the energy of visible light.
  - Understand that gamma emissions that come from excited nuclei do not change the identity of the isotope.

Assessment

The verb in this indicator is predict which means to draw a logical conclusion from presented information. In this case the students should be able to predict the resulting isotopes if they are told which type of decay will occur.

Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments should show that students can predict the products knowing the nature of alpha and beta particles and gamma radiation and how each type of decay would affect the nucleus.

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P-8.4 Apply appropriate procedures to balance nuclear equations (including fusion, fission, alpha decay, beta decay, and electron capture).

Revised Taxonomy Levels 3.2 B Apply procedural knowledge

In physical science students were introduced to the concept of isotopes and how to write symbols to represent different isotopes. Students may not have balanced nuclear equations.

It is essential for students to

- Understand nuclear symbols.
- Balance nuclear equations when given all of the particles on both sides of the equation.
  As a general rule:
  - The sum of the mass numbers "A" must be the same on both sides of the equation.
  - The sum of the atomic numbers "Z" must be the same on both sides of the equation.

Teacher note: This procedure can be linked as somewhat analogous to the procedure for balancing chemical reactions.

Assessment

The verb apply means that a major focus of assessment should be for students to show that they can "apply a procedure". The student must be able to apply the procedure for balancing nuclear equations.

The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure is application of the procedure for balancing nuclear equations. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar.

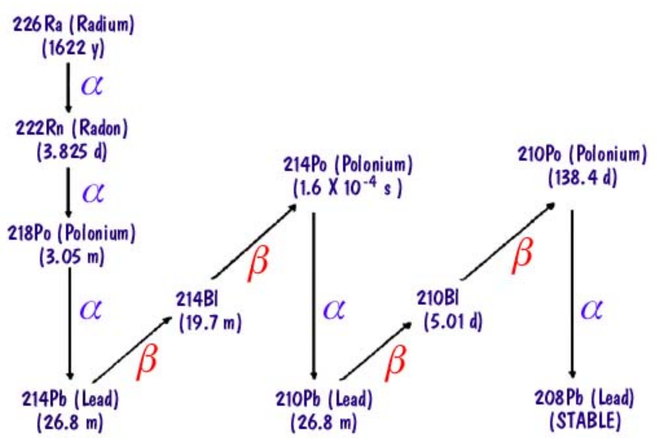
P-8.5 Interpret a representative nuclear decay series.

Revised Taxonomy Levels 2.1 B Interpret conceptual knowledge

In physical science students were introduced to the concept of radioactive isotopes. Alpha, beta, and gamma emission may not have been covered.

It is essential for the student to:

- ❖ Understand that a beta decay results when a neutron transforms into a proton and a beta particle.
- ❖ Understand that an alpha particle is a helium nucleus which consists of two neutrons and two protons.
- ❖ Understand how isotopes are transmuted into new isotopes trough alpha and beta decay.
- ❖ Understand half-life.
- ❖ Interpret a radioactive decay series such as the one below



Radium-226 (Uranium-238) decay series with half-lives.

Assessment

The verb for this indicator is <u>interpret</u> which means to change from one form of representation to another. Given a nuclear decay series the students should understand what is happening and relate this in words.

Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments should show that students understand the transformations involved in the decay series.

P-8.6 Explain the relationship between mass and energy that is represented in the equation $E = mc^2$ according to Einstein's special theory of relativity.

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

In physical science students were introduced to the concept of mass turning into energy in nuclear reactions and practical applications of this concept. Students are aware of the meaning of the equation $E = mc^2$.

It is essential for students to:

- Understand the equivalence of mass and energy.
- Understand that mass is a form of energy. A piece of mass even if not interacting with anything else has "energy of being" called rest energy. It takes energy to make mass and when mass disappears energy is released.
- The amount of energy E is equated to mass by the equation $E = mc^2$.
  - The quantity c^2 is a conversion factor. It converts the measurement of mass to an equivalent measure of the amount of energy.
  - In a nuclear reaction the total mass after the reaction is less than the mass before the reaction. The difference in mass is equivalent to the energy given off which can be calculated using this equation.
  - Exothermic chemical reactions result in mass loss as well but since the energy given off is relatively small the mass loss is very small and difficult to measure.
- Mass and energy changes apply to energy transformations other than nuclear and chemical reactions. Any change in energy changes mass.

Assessment

As the verb for this indicator is explain the major focus of assessment will be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model the relationship between mass and energy and the transformation between the two.

Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect model relating mass and energy and the transformation between the two.